Chapter

Governance for Sustainable Remediation of Polluted Soil in Developing Countries

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Abstract

Environmental governance is a challenge for many developing countries, and soil pollution is typically overlooked by authorities in the Global South. Soil governance should protect people and environment from the hazards of pollution and promote sustainable remediation of polluted sites through legislation and soil policies that facilitate the use of appropriate technology. Today, however, the soil governance landscape is highly fragmented and often fails to adequately address these concerns. Combining soil remediation with profitable activities (alone or in combination) such as food and fiber production, biomass energy production, erosion control, carbon sequestration, favoring biodiversity, etc. is potentially an appropriate strategy to promote the decontamination of polluted agriculture soil in low-income countries. Many potential pitfalls follow such a strategy but decision support tools may provide insights from the latest scientific remediation findings to stakeholders in their exploration of policy options. This chapter explores challenges and opportunities for sustainable soil governance in developing countries.

Keywords: soil governance, developing countries, soil pollution, bioremediation, DPSIR, phytoremediation

1. Introduction

Soil pollution i.e. presence in soil of substances out of place and/or present at higher than normal concentrations that has adverse effects on non-targeted organism, is a serious threat to food security and human health in developing countries [1–5]. At least one third of the world's ecosystems are currently suffering from different effects of pollution [6]. The exact scale of global soil pollution is unknown but according to some estimations, at least 22 million hectares may be affected globally [7]. Rodríguez-Eugenio et al. [4] argue that this number probably underestimates the scale of the problem. Due to insufficient data about the scale and implications of the problem, soil pollution is sometimes referred to as a hidden reality that is largely invisible to the international community [4, 8].

In developing countries, the magnitude of the soil pollution is largely an uncharted territory with limited knowledge of the extension and location of soil pollution hotspots. Soil pollution in developing countries comes from a number of sources. Often these are derived from anthropogenic processes, but also geogenic sources such as weathering and volcanic eruptions can be as important as anthropogenic sources in terms of risks to human health [9–11]. Large-scale application of persistent pesticides is one prominent source of pollution in developing countries, that has affected large areas of land historically [1, 3, 12] and in most countries in the Global South, inadequate applications of pesticides is an ongoing process that continues to pollute large areas of soil.

Soil pollution causes significant losses of income, as well as impacts on food security and direct hazards to human health. Typically, different groups of people are affected unequally by soil pollution. For instance, nutritionally marginal persons and women who tend to have higher percentages of body fat may carry more lipophilic pesticides and heavy metals which expose them to greater risks [13, 14]. Soil contaminants can enter the human body via three main routes: eating, inhalation, and dermal absorption. The exposure through *eating* can either happen indirectly by eating plants grown on contaminated soil, which are subsequently consumed by humans or by agricultural livestock or by direct ingestion of the soil (geophagia). Particularly, children under 3 years of age are susceptible to this kind of exposure that is one important pathway for human exposure to soil contamination. *Inhalation* and *dermal absorption* (through skin contact) is primarily a problem for agriculture workers who handle pesticides and a pathway from previously contaminated soil to humans [15, 16].

Among the different challenges that developing countries face, soil pollution is typically assigned low priority and is thus often overlooked by authorities in the Global South [13, 17–19]. Although progress has been made to strengthen the legal and regulatory frameworks during the last decades, poor environmental governance is still common in low and middle income countries and monitoring and enforcement of environmental regulations remains a challenge [20]. At the same time, experiences from remediation programs have shown that the complexity and cost of remediation and restoration tend to grow with time. Not only are the societal costs of inaction great but potential benefits (in terms of increased health, property values, poverty reduction etc.) from remediation projects may be substantial [20]. However, since those benefits tend to be collective rather than benefitting individual landowners or liable persons, even cheaper and less resource-intense remediation methods are often not perceived as lucrative, at least not as stand-alone technologies. In order to materialize, in developing countries, remediation projects on private or cooperative-owned land thus needs that the persons in charge of the polluted area perceive a strong, direct economic incentive from remediating the land [17, 18].

The need for innovative solutions to remediate the growing number of polluted fields in developing countries is increasingly urgent since the number of polluted sites that require remediation doubles every 25 years [21]. Many farmers in developing countries presently operate on polluted land, and the scarcity of agriculture land will inevitably force more farmers to cultivate food in contaminated areas as the human population increases [22]. A number of remediation technologies for polluted soil exist, ranging from expensive and resource-intense ex-situ technologies to slower and more cost-effective solutions that tend to be gentler on the ecosystems such as *natural attenuation*. Many of the conventional energy-intense solutions are unaffordable for most sites in developing countries except for some urban sites where the high land value would motivate the additional cost for a speedy solution. In areas of little economic value such as most rural areas in developing countries, the high costs involved in removal of toxic substances from polluted soils often prevent remediation from being carried out [23]. Often, time constraints are not as limiting as in industrialized contexts since alternative remediation options are typically non-existing. In addition to being profitable and provide perceptible and achievable benefits, soil remediation solutions for developing countries need to be cost-effective and compatible with the social and economic development state of the region.

One way to make remediation projects appealing in developing countries is to integrate the remediation project with value-adding measures such as production of energy crops, food production, erosion control, and carbon sequestration. Multifunctional production system that yield biomass for fuel, fiber, or safe food crops at the same as they remediate polluted soils and sequester carbon are potentially very appropriate methods in this context. Although such strategies may be appropriate options for most pollutants, a number of challenges and potential pitfalls need to be surmounted. Challenges may be associated with the application of the remediation technology since projects need to be tailor-made for the specific site they address. Commercial one-fits-all solutions can typically not address the heterogeneity and complex (socio-economic, cultural, and environmental) contexts of most polluted sites in developing countries. Other challenges are related to inadequate soil governance (such as inefficient laws, lack of policy and law enforcement) that may hamper the execution of appropriate soil remediation projects. The aim of this chapter is to explore governance and socio-institutional limitations and opportunities for development of appropriate soil remediation technology for developing countries.

2. Technology transitions

Technologies for soil remediation in developing countries need to meet a different set of criteria than in sites of high land value in industrialized countries in order to be adopted. First, polluted sites in developing countries are accorded less attention by authorities and investors compared to polluted sites in industrialized countries [24–28]. Furthermore, a great fraction of the inhabitants in developing countries are systematically denied full access to many opportunities, resources, and rights and prevented from participating fully in the economic, social, and political life of the society, which makes them marginalized and vulnerable to technological mismatches and unsustainable technology transfer [28].

The transition toward a sustainable society needs behavioral changes as well as implementation of new technologies. New technologies, improvements and adaptation of current technologies are crucial but the socio-institutional sustainability related to such technology transfers is often neglected when implemented in developing countries [29]. Sustainability transition analysis based on theories such as multi-level perspective or strategic niche management, often lead to a focus on increased resource efficiency but ignoring the risk that poverty creating structures are reproduced from one state to another in such transitions even if the resource turnover rate is decreased [30, 31]. In the Global South where technological, cultural and social needs differ fundamentally from the Global North, the lack of understanding of these mechanisms and the assumption that all problems of resource governance can be represented by a small set of simple models [32] often lead to technological and cultural mismatches when regional capabilities, objectives and benefits are neglected or expressed in unrealistic terms [12, 33]. Over-reliance on technological fixes in developing countries where access to technology is often limited may further add to this problem. Sustainability challenges such as soil pollution are by definition multidisciplinary and need a broad array of methodological tools to be disentangled. The failure to include views from pertinent scientific fields and political, cultural, and institutional dynamics in sustainability assessments tends to lead to misinterpretations and overlooking issues that are outside the scope of the expertise in the project groups.

Multidisciplinary visions are thus needed when analyzing different remediation options favoring the ones that contribute to catalyze the transition toward environmental, cultural, and socio-institutional sustainability. Conventional approaches to soil remediation typically focus on the internalities of a remediation project (effectiveness of the remedy, implementability, cost considerations, time constraints, etc.) [34]. The environmental viability of specific remediation technologies has traditionally received little attention from researchers, let alone the social aspects of remediation projects.

In order to be sustainable in developing countries, remediation methods need to be suited to the immediate socio-economic, cultural and environment contexts in which they are introduced [35]. One discipline that attempts to promote a technological transfer that address the issues of poverty, social equity, gender equality and basic human needs is the concept of *appropriate technology.* The grassroots appropriate technology movement had its peak during the 1970s and although the number of NGOs dedicated to the promotion of appropriate technology decreased during the following decades, the movement has not lost its momentum. Initially, advocates of appropriate technology prescribed solutions that should be small-scale, labor-intensive, low capital investment per worker, energy efficient, environmentally sound and controlled and maintained by the local community [36–39]. However, many theorists such as Ranis [40] argue that appropriate technology can also be advanced, modern, capital intensive, etc. depending on the available resources, local preferences, time, and place. In developing countries, soil pollution is found in rural areas as well as in relatively wealthy areas with high land values in urbanized areas, and the most appropriate remediation technology may look very different depending on the context. With a definition such as Ranis's, appropriate soil remediation technology should seek to maximize the society's objectives given that society's capabilities rather than categorically favoring low tech, small scale solution.

3. Governance instruments for sustainable soil remediation in developing countries

The design of soil remediation projects, no matter how appropriate they are, needs to be implemented to be able to reduce pollution. A significant risk in developing countries is that inadequate soil governance may hamper its implementation or impede remediation projects from materializing altogether. Soil governance may be defined as the network of formal and informal institutions (e.g. legal prescriptions, regulations, market incentives, rules, norms, habits, and attitudes) that concern soil-related decision-making processes of state and non-state actors at different decision-making levels [41]. The ultimate goal of governance for sustainable remediation of polluted soil is to protect people and environment from the hazards of pollution and promote sustainable remediation of polluted sites through legislation and soil policies and manage conflicts between stakeholders about soil [42, 43].

Despite attempts to unify soil governance efforts internationally by the Food and Agriculture Organization of the United Nations (FAO) who have established the Global Soil Partnership (GSP) [44], the soil governance landscape is still highly fragmented and soil and water pollution management policies are often not integrated with food safety policies [41, 45]. Even in the most stringently regulated countries, legislation applicable to soil pollution and food security often lags behind state-of-the-art, and in developing countries, this discrepancy is particularly palpable [45, 46]. As a result of this, legislation and policies often fail to adequately address problems related to soil pollution and food security [43, 45, 46].

3.1 Legislation

Legal frameworks and the implementation of these differ substantially between countries but in most low and middle income countries, regulation instruments are insufficient to address soil pollution [1, 43], and the lack of the enforcement of environmental laws leads to that huge polluted areas with unknown concentrations of numerous pollutants are used for agriculture, recreation or construction. The polluter-pays principle is a fundamental legislative principle that is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the environment. A variation of the polluter-pays principle exists that has been adopted by a number of developing countries, including India, Malaysia, Taiwan, Ecuador, Chile, Costa Rica, Kenya, South Africa, and among others, where the government instead is directly responsible for payment and environmental monitoring. According to an assessment of the two strategies, government-pays regimes may be preferable in situations characterized by widespread poverty, high interest rates and judicial delays and uncertainty—however, there is a risk that local governments choose a level of monitoring that minimizes the financial exposure of the local government but does not fully internalize the costs as well as the benefits of the agents' care [47].

To date, many developing countries lack specific laws on soil pollution prevention and management [4, 8]. Until 2018, there was no specific law governing soil pollution in China but a soil pollution action plan based on the law, with regulations, risk control rules, and technical guidelines developed by the Ministry of Environment and Ecology had a similar role. In August 2018, the Soil Pollution Prevention and Control Law was adopted as the first specialized law on soil pollution prevention in China. The law stipulates principles, measures, and goals of soil management and essentially adopts a protection-first and polluter-pays approach [48].

Two major legislative strategies are used to protect people from exposure to pollutants: maximum permissible concentrations (MPC) and different risk-based approaches and both strategies have their limitations in terms of protecting people from exposure to pollution. Limitations with MPC legislation include insufficient number of regulated pollutants [49] and concentrations that do not respond to up-to-date knowledge about toxicity [50]. MPCs are also largely limited to metals and thresholds of soil contamination by organochlorine pollutants are typically not available for agricultural use of the soil [51], and many developing countries have not developed their own MPCs but follow MPCs from other countries whose context may not be applicable. Critiques of risk-based approaches argue that although they can offer important benefits, they also face a range of epistemic, institutional, and normative challenges [52], which may be unsurmountable for administrations in developing countries that are already under considerable pressure.

3.2 Policies and standards

Development of policies for soil pollution and remediation in developing countries is a complex process that must consider not only the legal requirements but also technical practicability, scientific knowledge, economic, and cultural aspects, thus implying an intensive consultation of a high number of actors [44]. Since the 1970s, environmental policies have evolved from the prevention of local pollution to a more holistic management of the natural resources [53], but currently there is no global soil framework that has the agreement of national governments, and soil governance thus follows a fragmented structure from global policy documents and agreements to local attitudes and customs [44]. Since there is no global thematic strategy on soil protection, less all-encompassing standards and policies may be used, to prevent people from exposure to contaminated soil. There is a remarkable scarcity when it comes to international standards and guidelines to avoid exposure to soil pollution and the ones that exist commonly focus on food security or food production [4, 8]. The Codex Alimentarius, for example, is one such collection of internationally recognized standards, codes of practice, guidelines, and other recommendations relative to food production, and food safety that may fill some of the void and offer guidelines for soil pollution problems that are related to food production. The Codex Alimentarius provides guidelines for maximum concentrations of a substance based on WHOs maximum monthly intake that can be legally permitted in a commodity (food or feed) for a number of substances.

Good Agricultural Practices (GAP) is another collection of principles that applies to on-farm production processes as well as post-production processes to achieve safe and healthy food and non-food agricultural products. GAP uses a holistic perspective and training manuals on implementation of GAP typically include a number of aspects that are relevant to avoid exposure to polluted soil. Modules from such manuals include topics such as site history and management to identify risk of contamination from previous use of chemically or biologically hazardous substances, current use of fertilizers and soil additives [54]. Importing countries as well as domestic buyers can require producers to implement GAP, which may support the diffusion of the standard.

3.3 Decision support tools

Decision support tools are designed to support different stakeholders in the exploration of policy options in participatory processes by facilitating dialog and exchange of information. Such tools may have an important niche to fill in developing countries where legislation and policy may be deficient to provide insights from the latest scientific bioremediation findings to non-expert decision makers. For example, knowledge on bioaccumulation patterns of plants grown in a certain area could help regulators or change agents to emit informed recommendations on sound agriculture practices including species and cultivation protocols that are known to produce food with safe levels of pollutants. A number of attempts have been made to support decision makers with guidelines when designing sustainable remediation project in various contexts in developing countries by Haller et al. [17], Tang et al. [22], Clostre et al. [51], and others. In a critical review on decision-support tools for assessment of sites in need of remediation, Huysegoms and Cappuyns [55] conclude that the selection of alternatives is often inappropriate and that there is typically a disparity favoring the environmental aspect compared to economic and social aspects. Although social aspects such as human health and safety receives a considerable amount of attention but ethics and equity are seldom considered.

4. The *Driver-Pressure-State-Impact-Response* (DPSIR) framework for soil governance

The complexity of large-scale remediation projects in developing countries may seem like an overwhelming task to many actors. Employees at municipalities and county boards, NGOs, contractors, and consultants involved in remediation projects may benefit from frameworks such as DPSIR to structure particular environmental problems and identify appropriate responses

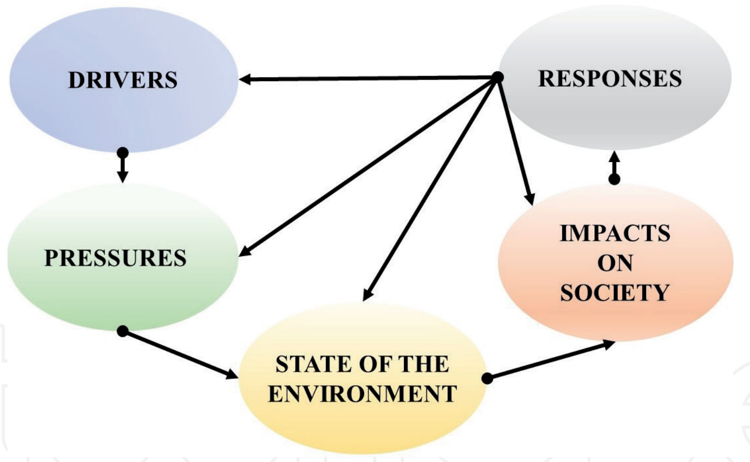

Figure 1.
A visual representation of the constituents and flows of DPSIR framework.

(**Figure 1**) [17]. DPSIR departs from the idea that there is a chain of causal links going from *driving forces* (fundamental social processes such as economic sectors, human activities, etc.) through *pressures* (human activities with impact on the environment), (environmental) *states*, *impacts* on ecosystems, human health, and functions to *responses* by policy-makers [56–60]. The DPSIR model has gained attention by researchers and policy-makers because of its multidisciplinary nature, its simplified, yet structured, methodological applicability in a number of environmental issues, its capacity to provide an overview of the problem in question and to identify policy options and solutions through the selection and monitoring of indicators and objectives or goals within each category of the model [60, 61]. Today, the DSPIR framework is a central component of Integrated Environmental Assessment, and it has been adopted as a strategy for United Nations Environment Programme (UNEP) among others [57, 58, 62–64]. The outcomes of a DPSIR analysis may be useful to narrow the communication gap among the scientific, political, and public spheres about soil governance issues, which makes this tool attractive for policy-making purposes. In Section 4.1, a case study from agricultural region Chinandega in Nicaragua illustrates how DSPIR can be used to structure environmental problems related to soil pollution in a developing country and to generate ideas on how to design soil remediation projects that are compatible with sustainable development in an economically vulnerable region.

4.1 Chinandega, Nicaragua—a case study of DPSIR application for soil governance

The region of Chinandega in Nicaragua is characterized by lack of financial power, low income, poorly implemented regulations, lack of public information about the pollution, etc. that often leave private farmers with no other alternatives than to grow their food in the polluted soils previously used for cotton cultivation [17, 65–68]. The DPSIR framework was used to describe the chain of causal links that define the soil pollution situation in the Chinandega region and identify interrelating cause-effect connections among the economic, social, and natural systems that are demanding soil remediation solutions. The analysis aspires to provide structured information that can improve the understanding of the scope of the problem and facilitate the identification of opportunities and limitations for implementing sustainable soil remediation initiatives in Chinandega.

Figure 2 shows a DPSIR scheme for the soil pollution situation in Chinandega. Given that Chinandega is primarily an agricultural region, the *driving forces* are characterized by the needs for agricultural food supply, income, and labor, coupled to a positive trend in population growth. Despite high per capita natural resources, Nicaragua is the second poorest nation in Central America and the agricultural workers are among the lowest paid in the country [66]. The lack of political willingness and the lack of awareness about the severity of the soil pollution issue among producers (local farmers) and their consumers are key socio-institutional *drivers* that aggravate the problem and perpetuate the lack of alternatives [17].

These *drivers* trigger a generalized poor management of the soils (i.e., *pressures*) with the excessive use of mineral fertilizers and chemical pesticides, inappropriate crop cultivation techniques, unsuitable livestock farming practices, etc. and altogether contribute to soil erosion, loss of soil fertility, and pesticides pollution. Land-use changes are also part of the *pressures* generated from the *drivers* above [69]. When the soil becomes severely degraded, farmers are forced to abandon the land and conquer new agriculture sites through deforestation [69]. The *pressure* of climate change arises from numerous global socio-economic *drivers*, and it is a source of many pressures on the environment itself. It also compromises the integrity of the less resilient socio-ecological systems at all scales all over the world [70]. In poor and rural areas like Chinandega, agricultural production, water resources, human health, and ecosystems are greatly affected by a changing local climate, all which increases considerably the vulnerability of the region and aggravates the situation by intensifying the magnitude of the pressures exerted on those systems. *Pressures* coming from the excessive use of mineral fertilizers and organochlorine/organophosphorus pesticides in the past can be categorized as *past pressures*; however, they continue to have an impact on the present *state* of the environment [17].

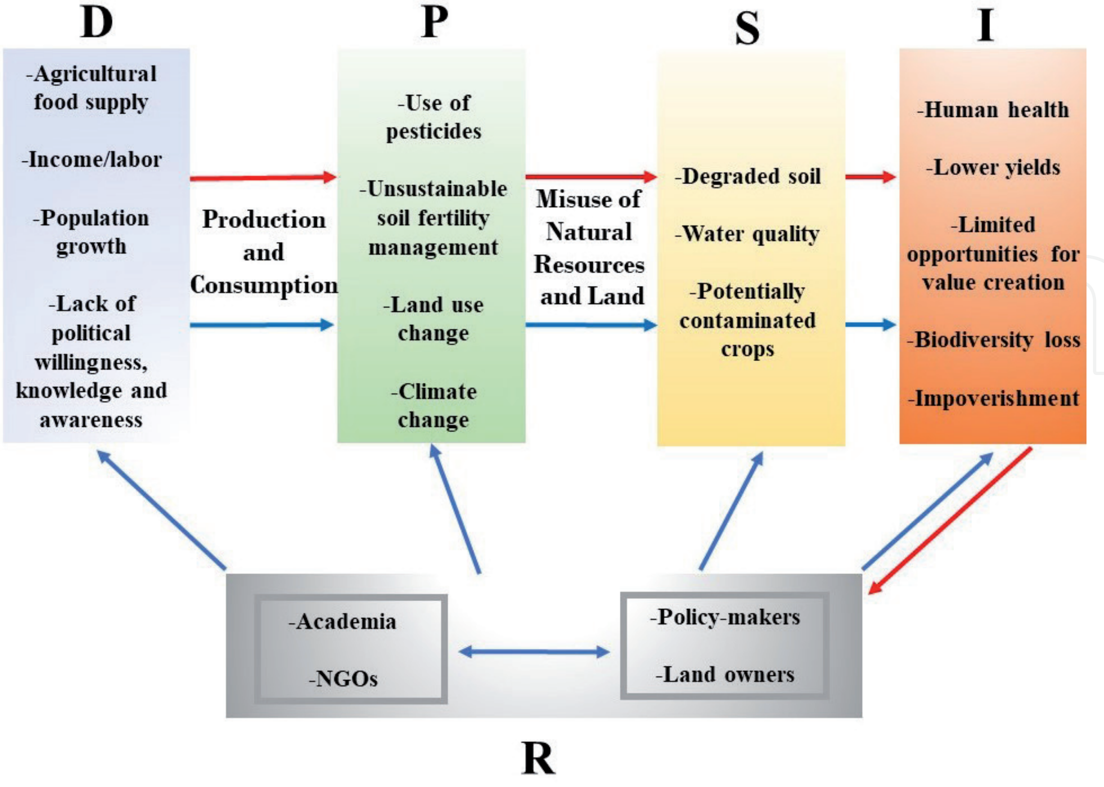

Figure 2.
Application of the DPSIR model in the context of Chinandega. Red arrows indicate the current situation and non-desired relations. Blue arrows indicate relations that are needed to promote a sustainable management of the soil resources in Chinandega.

The outcome of these *pressures* is a degraded and severely polluted soil (i.e., *state*). The degradation affects also the water quality of lagoons and reservoirs through the run-off and leaching from the polluted soils and potentially affects the quality of the agricultural production because of the uptake and translocation of the soil contaminants to the edible parts of the plants. As a result, this environmental *state* of the soils *impacts* the local and regional biodiversity because of the effects on the ecosystems (e.g., perturbation of trophic chains and the biotic phase of the soils, contamination of water sources, resistance to pesticides, phytotoxicity, etc.). The human health is also *impacted* by the local consumption of contaminated agricultural products and contaminated drinking water supply. The occupational safety and health of farmers that employ agrochemicals like pesticides and chemical fertilizers is also jeopardized [65, 68, 69]. Furthermore, because of the present pollution the land might suffer from economic devaluation which in turn could discourage greater investments to support, for example, soil remediation costs or more sustainable soil management practices. Lands being either over- or underused is a condition that is affecting not only Chinandega but all the agricultural regions in Nicaragua [66] and many other agricultural regions in developing countries. This condition reduces the capacity to take full advantage of the potential of the agricultural production which impedes the development of important market niches in the agricultural sector and also the mitigation of poverty in economically important rural regions like Chinandega. However, if the soil contamination problem is not addressed, farmers may find difficulties to export their agricultural produce because it might not meet international safety standards. The vast majority of the population in Chinandega relies on agricultural production as their principal means of support and farmers are thus the most affected social group by the *impacts* of the contaminated and degraded lands of the region. Obsolete and unsustainable agricultural technologies and practices and underpaid agricultural workers are some of the most important causes of impoverishment in Chinandega rural communities.

Nicaragua essentially lacks legislation that regulates the soil use except for some dispersed and not compulsory norms. Policy actions (i.e., *responses*) that address the soil degradation problem in the region of Chinandega are virtually non-existent. Lack of knowledge of the environmental repercussions, lack of political willingness to create soil policies that regulate soil use, uncertain land tenure, and the absence of legislative mechanisms are all reasons that hamper the development of sound soil governance in Chinandega. Hence, the societal *response* to the impacts (**Figure 2**) is insufficient to address the soil pollution sustainably. This vicious circle tends to maintain or deteriorate the current situation. Clearly, societal responses need to find other pathways that involve actors from different decision-making levels such as the local government and the landowners themselves. Most of the *drivers* and *pressures*, i.e., insecure agricultural food supply, income/labor issues, use of pesticides, land use change, and climate change need national legislation measures or political action from local governments in order to reverse the negative relations. The landowners however have a great potential to change their own fate by changing *pressures* such as land use and soil fertility management, which will positively influence *states* such as degraded soil, water quality, and contaminated crops and in the long run even *impacts* such as human health, low yields, limited opportunities for value creation, and biodiversity loss. The landowners may not currently possess the necessary knowledge to implement such a change in land use habits but change agents such as academia, and NGOs may promote the necessary knowledge transfer to catalyze such a change. NGOs can also promote an active citizenship that will put pressure on politicians and dissuade lack of political willingness.

Academia and NGOs operating in the region therefore plays a crucial role to stimulate the necessary changes of *drivers* and reduction of *pressures*. Institutional bodies such as universities (e.g., UNAN-Managua) in collaboration with their international scientific and educational partners (e.g., Mid Sweden University, University of Brasilia, Monaco's International Atomic Energy Agency, Technical University of Lisbon, Danish Aarhus University, Norwegian Institute for Water Research, etc.) have promoted scientific investigations on historical and current sources of contamination affecting soil, waters, crops, and human health. Although such research projects have increased the awareness within the scientific community, to date, this knowledge has not efficiently reached the local communities, nor has it brought forth responses by means of remediation projects.

Locally active NGOs (such as Proleña and Chinantlan) together with academia are therefore important drivers of change with great potential to influence public policy-making in terms of creating awareness of soil pollution problems and potential solutions. The low economic capacities and low priority given to soil pollution by local governments together with the predominantly private tenure of the land places a major responsibility for the remediation on the individual landowners [17, 65, 66]. NGOs and academia have a more direct impact by stimulating landowners to adopt multifunctional land-use strategies that address many of the regions sustainability problems simultaneously. Productive systems can be designed in a way that, in addition to remediating the soil, also provide a source of income or address other scopes of the common agenda and deliver perceivable, direct economic incentives for the landowners [17, 18]. Multifunctional land-use production systems (of food or biomass for energy) with capacity for phytoremediation are low-cost solutions compared to conventional physicochemical soil treatments. Such low-cost systems could potentially produce high outputs in terms of socio-ecological and economic benefits (e.g., more resilient agricultural systems, provision of societal goods and services, soil and water quality enhancement, biodiversity conservation, and reduction of poverty). In the case of Chinandega, a marginalized region with high dependence on agricultural production, these motivations are significant when it comes to the screening of alternatives to solve the soil contamination issue of the region and the consequences arising from it.

5. Prospects for sustainable remediation of polluted soil in developing countries

Sustainable remediation of polluted soils in developing countries must meet and surmount many challenges. Important challenges identified in this chapter relates to technology transitions and soil governance. Technologies for soil remediation in developing countries need to meet a different set of criteria than in industrialized countries and should be designed to meet the immediate socio-economic, cultural, and environment contexts in which they are introduced. Sustainable technology transitions must be aligned with the development and application of suitable legislation, policies, and standards. Improvements or development of new soil legislation and policies need to be locally adapted, match the latest scientific progress, and be flexible enough to allow innovative solutions. The DPSIR case study of the region Chinandega, Nicaragua demonstrates a number of drivers that lead to unsustainable production and consumption patterns that in turn adds pressure to both agricultural and natural systems in the region. Past pressures (e.g., excessive use of persistent pesticides) and external pressures due to climate change complicate the situation and aggravate the effects of misuse of natural resources and land. The result is toxic and degraded land (state) that is detrimental to the ecosystems, people's health and to opportunities for value-creation from agriculture production. The responses are currently insufficient to promote sustainable land use, but the DPSIR analysis suggests some ways forward. To address the pollution problem, academia and NGOs have a crucial role as change agents to support policy-makers and farmers with decision support and promote multifunctional strategies that can remediate polluted soil but also provide a source of income or/and address other scopes of the common agenda. An important learning outcome of this DPSIR analysis, which is applicable to other regions in developing countries, is that soil governance at all decision-making levels should be aligned to promote cooperation between academia, NGOs and policy-makers that jointly can stimulate a gradual change toward sustainability and reduction of the soil pool of pollutants.

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